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Neutron transport methods for accelerator-driven systems
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A Monte Carlo model of an Accelerator Driven System (ADS) has been developed using the MCNPx code. Our MCNPx model consists of the following major components.

1. The proton accelerator tube
2. The target
3. Six nuclear fuel assemblies placed symmetrically around the accelerator tube in a cylindrical geometry.
4. A “blanket” placed between the assemblies and at the periphery of the ADS

The model, like any Monte Carlo model is flexible enough so that the number and type of spent fuel assemblies can be rearranged or changed; use was made of the “repeated structure” features of the MCNPx combinatorial geometry capabilities for the accurate representation of all the components of the ADS.

Three models were developed to allow for an in-depth comparison of a fairly detailed heterogeneous model to a very simple model of only rings with homogenized compositions. The three separate MC models used are: (1) homogenized rings of water and water plus nuclear fuel, (2) homogenized fuel assemblies in water, and (3) individually modeled fuel rods in water (see attached Fig. 1 and 2). The different models each have there own purpose; Model (1) acts as the simple model for comparison with a deterministic calculation to be done with VARIANT in (r, z) geometry. Model (3) is the most detailed one, having the minimum amount of homogenization and model (2) provides a bridge between model (1) and (3) (it could be considered a semi-homogeneous model).

To be able to obtain results having acceptable uncertainty with this MC calculation, a variety of variance reduction techniques such as weight windows, particle importances, and geometric symmetry were used. To reduce the CPU demands for the computation, a neutron energy spectrum was initially determined assuming 150 MeV protons strike a tungsten target. The target was large enough to ensure all protons would interact and create spallation neutrons. The ENDEF-60 cross sections for up to 150 MeV were utilized for this part as well as for the rest of this work. A search is currently going on for higher energy cross-sections to produce more data (the search is for anything between 150 and 800 MeV libraries). A neutron energy spectrum was determined for use as a source in all-subsequent calculations Criticality calculations were performed to ensure the system was sub-critical. For all three models the value of k is ~0.76.

To determine the neutron flux, point detectors were placed in matching locations, along the R and z directions, in each model, for comparison. Flux values were obtained as a function of radial distance for several z levels. After proper comparisons of the models are performed, more flux tallies will be applied to the detailed model in the form of volume tallies to create a better model flux mapping.

Initial results have been compiled and analyzed for selected z-planes in the model (see Fig. 3). Although the differences among the three models are small, the general trend shows that as the homogenization increases the flux increase. It should be noted that the statistical error of the calculations were less than 10 %, generally, the differences between the fluxes were greater than the difference between the statistical errors. The only overlapping of the fluxes, at r = 28 cm, we attribute to statistics instead of a real increase in the flux. The shape of the energy spectrum is the same, within statistics, in the three models. The data at this point in our study shows that complete homogenization causes notable difference in the flux. However, there is no real difference between the fluxes obtained with models (2) and (3), i.e. there is no real difference when modeling homogenized assemblies explicitly and when modeling individual rods explicitly.

In parallel with the above work, deterministic transport methods are under development. These are being incorporated into prototypical forms of the VARIANT code at Argonne National Laboratory, and will subsequently be integrated with the Monte Carlo work discussed above. There are two deterministic thrusts. The first is to implement the variational nodal method in the r-z geometry needed for ADS preliminary studies, and the second is to find a method for treating void nodes needed to model the accelerator beam tube within the variational nodal framework.

We have successfully implemented r-z geometry diffusion theory in VARIANT, and tested the algorithms on a number of multiregion one- and two-group model problems. Both "*h*" and "*p*" refinement have been examined to assure that eigenvalue convergence is obtained with mesh and/or polynomial refinement. The treatment of the spatial variables in the diffusion (or P1) formulation is presently being integrated into a more general spherical harmonics (Pn) formulation.

Working closely with Argonne National Laboratory staff member M. A. Smith, we have continued to explore methods for treating void regions within the second-order transport methods used in the VARIANT code. After a number of false starts, we believe that we have obtained response matrices utilizing a particular form of first-order spherical harmonics approximation that is compatible with second order transport codes. The method is currently being tested on simple model problems programmed in MathCAD while we attempt to better understand the theoretical underpinnings that cause this method to succeed wile the others have failed. We are particularly excited about this development since to date the treatment of void regions has been the “Achilles’ Heal” of all diffusion and transport computational methods based on the spherical harmonics approximation.

The Monte Carlo results discussed above will be presented at the November ‘03 ANS meeting. Our intent is to submit one or more papers based on the deterministic developments to the PHYSOR2004 meeting to be held in Chicago next April.

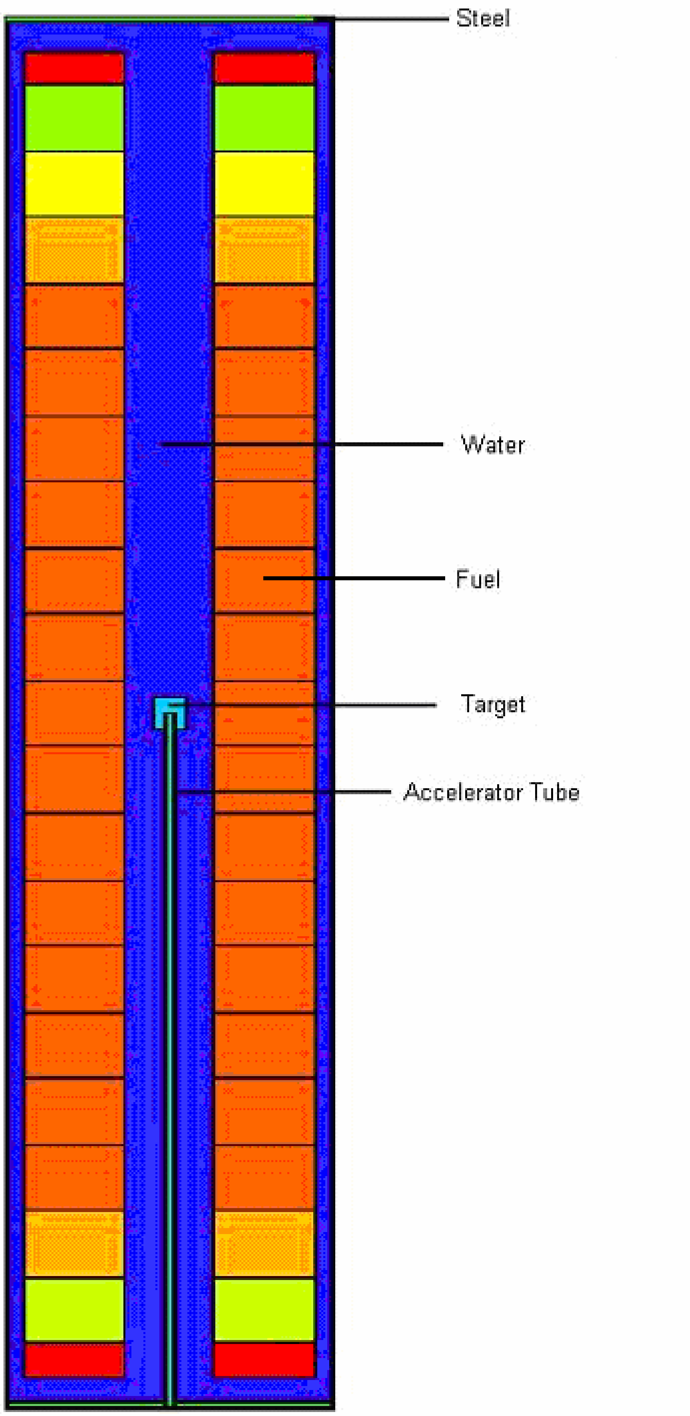
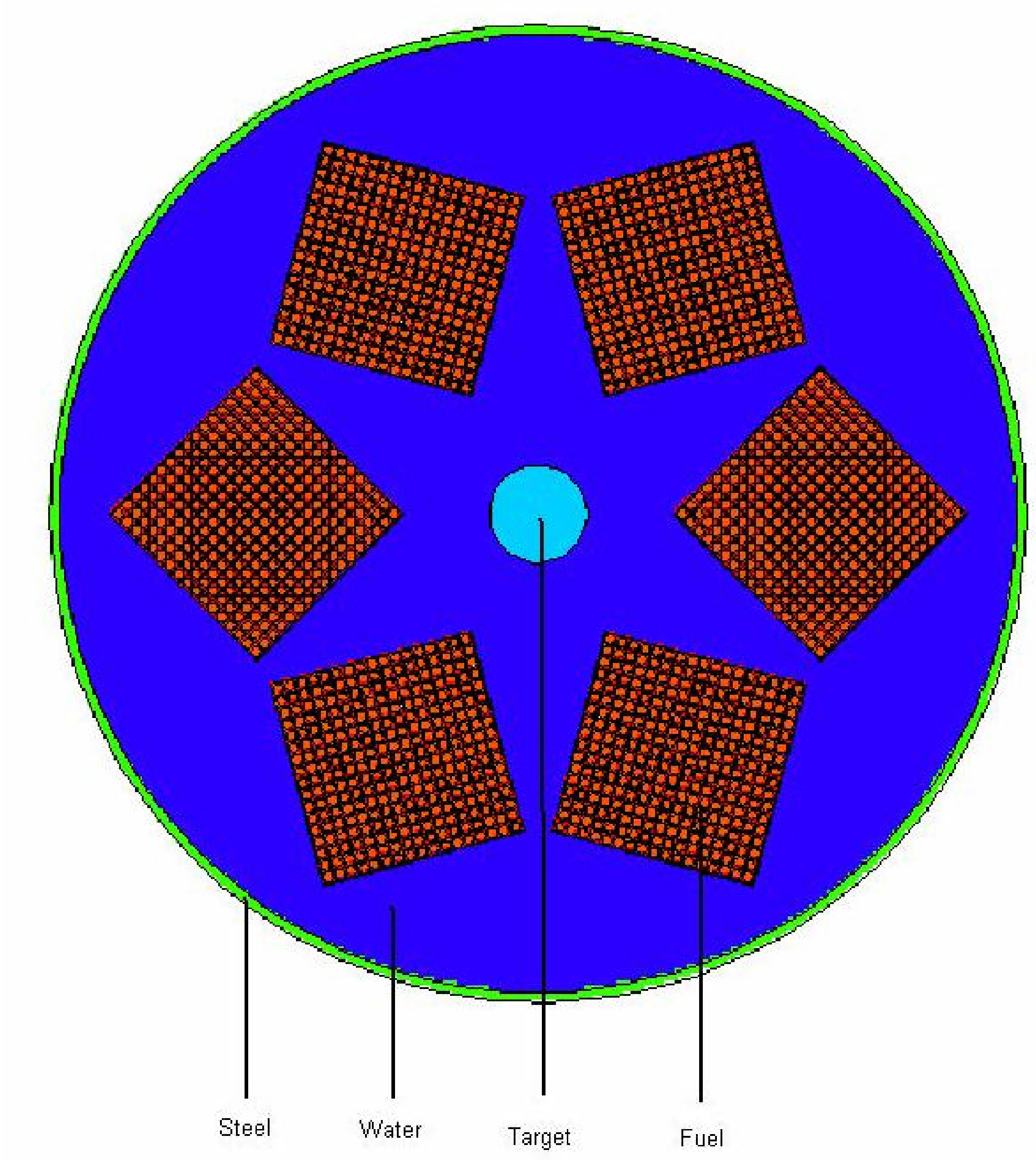


Figure 1. x-z view of homogenized assemblies model



Firgure 2. x-y view of detailed model with rods present in assemblies

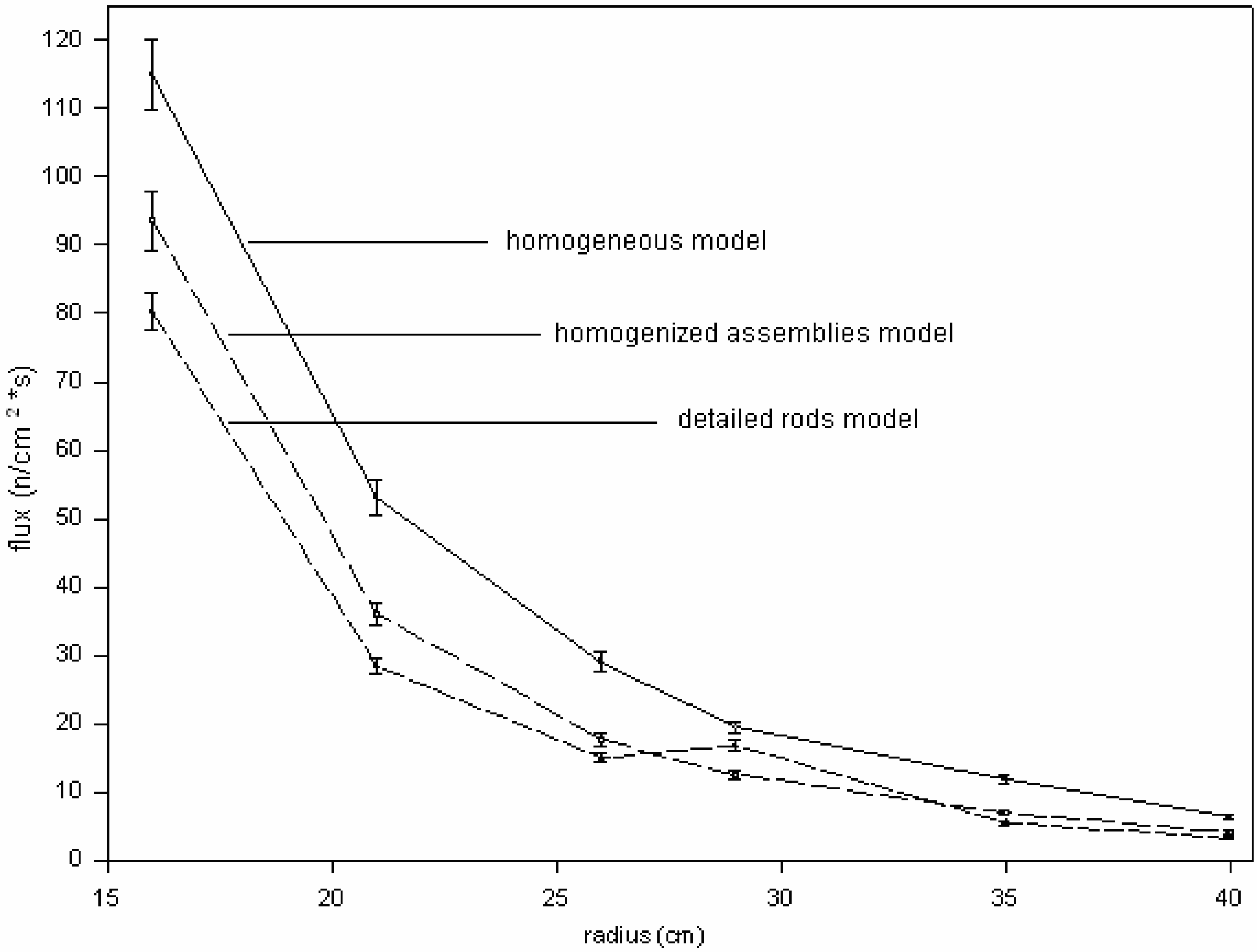


Figure 3. ϕ?(relative values) vs. r for all three models; ♦ homogeneous, assembly, Δ rods